

The Satellite Design Course AENG 468 at Tuskegee University as an Example to Implement ABET EC 2000

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Abstract -This paper shows that the satellite design course AENG 468 can be considered as an excellent model to implement the new ABET criteria. ABET EC 2000 is composed of eight criteria that emphasize quality and professional preparation for engineering students. The author has developed AENG 468 during the last five years, and the course is offered to aerospace engineering students at Tuskegee University as a technical elective. The author taught the course focusing on criterion 3 of ABET EC 2000. The paper discusses the development plan, the instruction techniques as well as the assessment procedures to evaluate the outcomes of criterion 3.

Key words: satellite design course, ABET EC 2000, course description, assessment.

INTRODUCTION

The new ABET EC 2000 is composed of eight criteria that emphasize quality and professional preparation [1 and 2]. Successful implementation of ABET requires collective and coordinated work from the faculty of all engineering departments. Continuous review of course development procedure, teaching methods and evaluation procedure is essential to produce students that can achieve the eleven requirements of criterion 3 of ABET 2000. It will be difficult to implement AEBT 2000 successfully if the faculty does work as a team to achieve criterion 3. An integral part of the faculty job is to write the course objectives, to improve teaching methods, in the class and labs, and to evaluate students' learning to achieve ABET criteria. In an effort to give a model for faculty members, I have developed the satellite course in the aerospace engineering science department, Tuskegee University, as an example of a comprehensive effort to implement criterion 3 of ABET 2000.

Organization of the paper

The paper will cover the following topics in the given sequence:

1. Satellite design course development plan
2. Course syllabus
3. Course description and content
4. Course activities
5. Grading
6. Instruction Techniques
7. Evaluation
8. Correlation to EC criteria 3

1. COURSE DEVELOPMENT PLAN

The Satellite design course is developed to achieve the goals of the college of engineering and the objectives of the aerospace engineering department in addition to ensure ABET EC 2000 criterion 3. The course objectives are

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derived to be consistent with the professional component of ABET EC 2000, the college of engineering goals, and aerospace department objectives. The course has main two fundamental components:

1. Knowledge component. This component requires a multidisciplinary engineering background.
2. Skills component which includes design skills, teamwork skills, communication skills, and problem solving skills. In this component students should be able to use their mathematics and physics skills in the design process.

In the course development, I favored the definition of curriculum as a dynamic system of four interacting elements that are responsible to achieve the goals and objectives mentioned above. The four elements are the objectives, the content, the instruction techniques, and the evaluation methods. In the following sections the various items of the course will be described. These are course aim, course objectives, learning tasks, learning activities, course content, instruction techniques, and course evaluation. Section 8 explains the correlation between the course objectives and ABET EC 2000.

2. COURSE SYLLABUS

Aim: This course aims to provide engineering students with a broad background necessary for the design and analysis of a satellite. This includes the different subsystems of the satellite.

Course outline: Introduction to the design of satellites includes aspects of mission design, components of a satellite system, orbital mechanics (astrodynamics), atmospheric entry, attitude determination and control, thermal control, structure and mechanism, power, propulsion systems, launching rockets, sensors, communication and telemetry, space environment and space debris. A group design project will use the learning experience of students to practice early stages of satellite design process.

Prerequisites: AENG 340 (orbital mechanics), or instructor permission.

Goals

The goals of the course focus on the knowledge and skills required of an aerospace engineer graduate. After completing this course students should be able to:

1. Achieve the course objectives.
2. Read, summarize, and discuss a new topic.
3. Write a technical report about a specific satellite subsystem.
4. Communicate new knowledge using Power-Point.
5. Examine the understanding of the classmates by writing questions and correcting their answers.
6. Work in a team.

Course Objectives

After completing this course students should be able to:

1. Discuss the mission statement, mission objectives, requirements and constraints.
2. Outline the main elements of a satellite.
3. List the satellite bus subsystems.
4. Discuss orbital description of satellites.
5. Describe the satellite structure and materials.
6. Describe the thermal control subsystem.
7. Describe satellite power subsystem.
8. Describe satellite propulsion subsystem.
9. Describe satellite communication and telemetry subsystem.
10. Design and analyze satellite's attitude determination and control subsystem.

11. Outline the preliminary design steps for a small satellite.

Course References

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3. COURSE DESCRIPTION AND CONTENTS

The course consists of two parts as follows:

Part I: Introduction to Satellite Design

This part covers the following topics:

1. Outline the main elements of a satellite.
2. Mission statement, mission objectives, requirements, constraints and satellite specifications
3. Elements of Orbital mechanics/astrodynamics
4. List the satellite subsystems
5. Communication, telemetry, tracking, command and control (data and voice uplink and downlink)
6. Atmospheric entry
7. Launch vehicle dynamics and rocket performance.
8. The space environment
9. Space debris
10. Satellite design: Outline the preliminary design steps for a small satellite.
11. Satellite design: Mission requirements, constraints and specifications
12. Small satellite university projects. Primary and secondary payload
13. Computational algorithms
14. Manufacturing and assembly

Part II: Introduction to Satellite Design Project

Students will work as a team to design a small satellite. The small satellite design project will take the San Jose satellite project as a model.

4. COURSE ACTIVITIES

Course activities focus on knowledge and skills related to the course objectives and the expected course outcomes. Course activities consist of three main elements which are presentations, tests and a design project. After conducting these activities students should be able to:

- Communicate through presentation (speaking skills).
- Summarize a chapter (comprehension and technical writing skills).

- Prepare a Power-Point presentation (communication skills).
- Work as a team to produce final project report (teamwork skills).
- Practice design concepts and skills through team work (design skills).
- Write tests to evaluate students' learning (evaluation skills).
- Correct test objectively (ethical element).

The above objectives will be achieved through the following:

I. Presentation

Each student will prepare and present selected topics from the reference list. He/she will write a summary of the chosen chapters and distribute it to his/her classmates.

II. Tests

Each student will write an examination paper for each chapter he/she presents to test the learning of other students of the class. All tests are take-home examinations. Correcting the test is the responsibility of the students. If any student copies the answer from any other student, both students will take a zero in this test.

III. Design project

During the semester, students are required to work as a team to design a small satellite for Tuskegee. Students must follow the steps described in the class notes. Mission statement is the first step in the design project. A final written report, using MS Word, and Power-Point presentation are integral parts of the final grade.

Class organization

The first part of the course is the responsibility of the instructor. He will give an overview of the satellite design course, its multidisciplinary nature, and explain the syllabus and the ABET EC 2000. Also, the instructor will explain to the students his role and their role in the learning process, and explain the grading systems. Grading will be based on students' efforts to achieve (a) through - (k).

In the first few classes the instructor will give a brief, concise and accurate description of the main topics of the course. He will ask the students to prepare detailed class notes for all topics of satellite design. Students will select their favored topics, and select the reference from the given list of references. Also, students will be encouraged to add additional references to the list. Students will select a leader from among them to coordinate the classes and prepare a schedule of presentations. Each student will be responsible to read and summarize his chapters. Each student will discuss, in the class, the technical points of his selected topics. He will write a summary and prepare Power- Point presentation. He will write tests to examine the understanding of his classmates. Finally he will correct the tests and discuss with the students his main comments. All the above activities will be under the supervision of the instructor.

Design Project

In designing a small satellite, the first step is a group discussion to select the satellite mission, mission objectives, mission requirements and mission constraints. For satellite subsystems each student will be responsible for designing a subsystem based on his selected topics. The team leader with the instructor will work as system engineers to integrate the work.

Instructor's role

1. Give the general plan of the classes.
2. Design the learning activities.
3. Brief the students about ABET 2000, learning outcomes, and criterion 3.
4. Introduce the main topics of satellite design.
5. Design and implement evaluation procedures.

6. Acts as a movie director or a maestro to conduct the students' class activities.

Students' role

Each student will present a few topics; this will depend on the number of the students in the class. The topics are: Mission analysis, Systems engineering, Space environment, Atmospheric entry, Space debris, Astrodynamics, Propulsion, Attitude determination and control, Power, Thermal control, Communication and telemetry, and Structure and mechanisms. The small satellite project will be based on the San Jose satellite project (web site: <http://www.engr.sjsu.edu/spartnik/>)

5. GRADING

To satisfy the course goals and objectives, the following points will be taken into account. Grades will be based on:

1. Students' comprehension of the topics.
2. Students' communication skills to present a topic.
3. Students' use of Power-Point for chapter presentations.
4. Students' use of MS Word to write chapter summary and tests.
5. Students' ability to follow the technical writing rules.
6. Students' ability to write relevant questions.
7. Students' ability to correct test papers.
8. Students' ability to use formulae in designing satellite subsystem.
9. Students' Teamwork activities to achieve the project goals.

The grade will be based on:

1. Weekly progress (20 %)
2. Power-Point presentation of the selected chapters (20 %)
3. MS Word written summary of the selected chapters (20%)
4. Ten questions and answers of each chapter (10 %)
5. Final project (Report & presentation) (30%)

Note:

Each presenter is expected to grade all other presenters. The score of each presenter should be based on the following:

Late or on time
Clarity of presentation
Boring/interesting
Interaction with other students
Informative and usefulness
Method of presentation

Class rules:

- If you come more than 5 minutes late you will be considered absent.
- Use Power-Point for class presentations.
- Use MS Word to write chapter summary and tests.

6. INSTRUCTION TECHNIQUE

The instruction technique of this course focuses on objectives-oriented learning. The main elements of the curriculum are course objectives, course content, instruction techniques and evaluation. These elements should work

interactively in a feedback manner to achieve the goals of engineering education. Teaching is a fundamental element in any education system. Teaching is included in the instruction techniques element of the curriculum.

The following are the main elements of the author philosophy of teaching:

- Teach with the main goal to achieve ABET EC 2000 criterion 3.
- Replace teaching by learning through changing the style of lecture presentation in class. The instructor's role should be similar to a movie director; this will help to reduce the classical mode of lecturing.
- Use diverse activities for students in the class/lab. Class activities should be student-centered instead of instructor-centered.
- Increase students' interaction towards learning. Small group teaming to discuss and solve problems.
- Encourage students to take notes and rewrite these notes in a more clean form in a binder. Each student should have a personalized class binder for each course that contains his class notes and the rewritten class notes, assignments, projects, reading, etc.
- Train students to write examination papers and the model answers.
- Train students to explain part of the course and use Power-Point for presentation.
- Train students to read and summarize main points of a course.
- Train students to combine theoretical, computational and experimental methods to analyze and solve problems.
- Introduce the main concepts of critical thinking in class activities and train students to practice them.
- Train students to use modeling and computer simulation as an advanced tool to analyze and solve problems.
- Train students to use the well known methods of problem solving.
- Train students to communicate in writing, presentation and group discussion. Assessing the ability to communicate effectively is not as simple as requiring a student to pass a series of courses on writing and reading. Communication skills, including writing, speaking, and group-discussion, will be put in practice by students in the classroom through student-centered class activities, as opposed to the more usual instructor-based lecture. In the student-centered setting, each student will prepare and present part of the course, providing summaries and Power-Point lectures based on the course objectives. Students should discuss the material in the class, and should be trained to write tests and quizzes to evaluate the learning of their classmates. The role of the instructor will become similar to the role of a movie director in conducting and guiding students to organize, present, and evaluate the materials.
- Use varieties of evaluation measures, e.g. homework, examinations, tests, quizzes, interviews, projects, and students' presentation to assess students' learning of objectives of the course, of new skills, and of new concepts

7. EVALUATION

Assessment of students' learning is an essential part of the learning process [3 – 9]. Both instructor and the students will evaluate the course. The evaluation is based on the degree of achieved goals and objectives of the course. This includes knowledge and skills acquired by the students after completing the course. A table including these elements will be used by students and instructors to evaluate the course outcomes. Student evaluation of the course will focus on their experience of (a)-(k) items of criterion 3. The instructor evaluation will measure the professional component related to the engineering knowledge of satellite subsystems, and the skills expected from the students.

Satellite subsystems knowledge module of the course should show the students' ability to explain and use mathematics and physics in analysis and design of satellite subsystems. During the course students will use their engineering background of fundamental concepts of mechanics, heat, fluids, structure, programming, and differential equation. Communication skills will be assessed via the class discussion, answer-question tests, presentation, reading and writing. In addition to that the problem solving and team working skills will be evaluated during the design project. Feedback from this evaluation process will be used by the instructor to improve the objectives and the learning activities of the course for the next semester.

8. CORRELATION TO ABET EC 2000 CRITERION 3

The following is a correlation between the learning activities of this course and (a) through-(k) items. Criterion 3 of EC 2000 requires that engineering programs must demonstrate that their graduates have the following:

(a) An ability to apply knowledge of mathematics, science, and engineering

The following topics covered in the courses are related to this item:

- Astrodynamics: Knowledge of this topic covers the orbit selection, orbital element, matrix transformation, different coordinates systems, satellite coverage, satellite lifetime, orbit transfer, and tracking
- Stress analysis: Knowledge of this topic covers the load analysis, different types of loads, selection of material, vibration analysis and different bus arrangements.
- Attitude control: Knowledge of this topic covers the control theory, rigid body motion, torques and moments to control the satellite, role of propulsion in control, and different mechanisms employed in the control.
- Communication: Knowledge of this topic covers the selection of frequency band, interface with computers, sending and receiving, data storage, and antenna design.
- Power: Knowledge of this topic covers the primary power and secondary power, power budget, solar cells, fuel cells, and other types of power generating source.
- Propulsion: Knowledge of this topic covers the different types of propulsive systems, solid and liquid propellants, the selection of the rocket motor, and the rocket performance
- Thermal control: Knowledge of this topic covers the different types of heat transfer, passive and active control of heat, and the selection of suitable material for insulation.
- Atmospheric entry: Knowledge of this topic covers the main equations used to study different entries into the atmosphere, and the various simplifying assumptions.
- Space environment and space debris: Knowledge of this topic covers the different phenomena and events astronauts and space engineer should deal with in outer space.

(b) An ability to design and conduct experiments as well as to analyze and interpret data

This item is related to the small satellite design project, and the mission design

(c) An ability to design a system, component, or process to meet desired needs

This part is included in the design project. Students will show how they can use satellite design to solve problems, to write a mission statement, and to derive mission objectives and requirements. The requirements will help them to determine the pay load, to design the satellite sub-systems, and to design the launch vehicle adapter (LVA).

(d) An ability to function on multidisciplinary teams

Students' preparation of a wide range of topics, with mutual consultation with the instructor, class discussion, different background of students show the multidisciplinary nature of the course. Students from different departments, AE, ME, EE are a good indication of the multidisciplinary team. It is clear from the above description that designing a small satellite is a multidisciplinary team work.

(e) An ability to identify, to formulate, and to solve engineering problems

This item is related to the students' work to design a satellite subsystem to achieve specifications and requirements. This ability can be enhanced through students' selection of the mission (military, scientific, commercial or civil service) to solve problem via satellites.

(f) An understanding of professional and ethical responsibility

Writing and correcting tests, forming a team, coordinating the work, assigning different tasks, following the class rules are example of ethics in action.

(g) An ability to communicate effectively

Group discussion of each chapter in the class, presenting a topic using Power-Point, writing a summary using MS Word, are examples of training students to communicate effectively. Another part of the project is asking students to communicate with companies to discuss with them the possibilities of accepting their design as a secondary load. This part is planned but not performed. It is part of the engineering profession training. Boeing and Lockheed companies are expected to be consulted.

(h) The broad education necessary to understand the impact of engineering solutions in a global/societal context

The different types of missions discussed during the selection of the small satellite mission covers this item. Students discussion of different security issues, SDI project, communication satellite goals, global warming issues, pollution, and various scientific experiments conducted in space are examples showing engineering solution in a societal context.

(i) A recognition of the need for and an ability to engage in lifelong learning;

Discussing various space missions, explaining shuttle problems, exploration of space projects as well as using space for different purposes motivate students to continue their effort to learn more about the outer space. Also, asking students to use different references for the same subject, and requesting each student to read a topic from a different text will help students to search for new references. It is clear that the class activities are good training to prepare students for lifelong learning.

(j) Knowledge of contemporary issues

This item is covered in the topics of space travel, NASA Shuttle problems, space debris, space environment, global warming, using space environment to manufacturing clean products, the pollution problems, space garbage, star wars, SDI, controlling the space, depletion of Ozone layer, WMD, energy and fuel cells, and space exploration.

(k) The ability to use techniques, skills, and modern engineering tools necessary for engineering practice.

In the various topics covered, different software are mentioned including different tracking software. Some students used the available CFD software (STAR CD) to generate geometry. Students learned some techniques used for clean room design. Also, many students used MATLAB software for calculation and plotting. Other students explored the usage of various commercial software for structure analysis.

9. DISCUSSION

The satellite design is an example of a course of a multidisciplinary nature. It can be used to implement the third criterion of ABET 2000 in the classroom. The author offered this course in the last five years and showed that criterion three can be used to assess students learning outcomes via this course. Students from different departments registered for this course, and the instructor was lucky because the number of students attended his class was small. In general five students registered for this class. On the average three students from aerospace engineering, one student from electrical engineering and one student from mechanical engineering. The main problem facing the instructor is the lack of the necessary background of engineering subjects of the students. In general students do not remember the necessary concepts from mechanics, strength of material, stress analysis, thermodynamics, fluid mechanics, heat transfer, orbital mechanics, propulsion, instrumentation, electromagnetism, control and signal analysis. Another problem is that many students have not a concrete understanding of the word “engineering design”. This was clear from my weekly discussions with the students and from their monthly report. Based on that one semester is not enough to complete this course as described. My students are not used to a multidisciplinary

course and they are not trained enough to work as a team. Instructors' feedback is important. The faculty should meet regularly to discuss the common problem regarding students learning and how to measure (a)-(k) criteria. Another issue regarding the term "ethical", in item (f) of criterion 3, needs a thorough discussion. Is ethics a behavior students should be trained to follow? Or is it course material students should study as other courses? Is passing a written exam about ethics, in order to complete the graduation requirements, enough to achieve item (f) of criterion 3?

10. CONCLUSION

This paper discusses all aspects needed to develop a technical elective course taking into account ABET EC 2000. The satellite design course development plan, described in the paper, includes the following: course syllabus, course description and content, course activities, grading, instruction techniques, and evaluation. The last section of the paper discusses the correlation between EC criteria 3 and the course activities. The author hopes that the reader of the paper may want to develop a similar course with similar objectives in an engineering area other than satellite design. The author believes that this paper could provide an excellent blueprint for doing so. In conclusion, consultation, coordination, and teamwork of all faculty members are essential for a successful implementation of ABET 2000.

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